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Temperature-Time Curves for Real Compartment-Fire Conditions

K. Mohammadi

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Disclaimer

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Kazem Mohammadi, Safety Analyst

Lawrence Livermore National Laboratory

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Background

- ASTM E 119 curve developed in 1917 is the generally accepted standard method in US for evaluating and rating fire resistance of structural-type building fire barriers

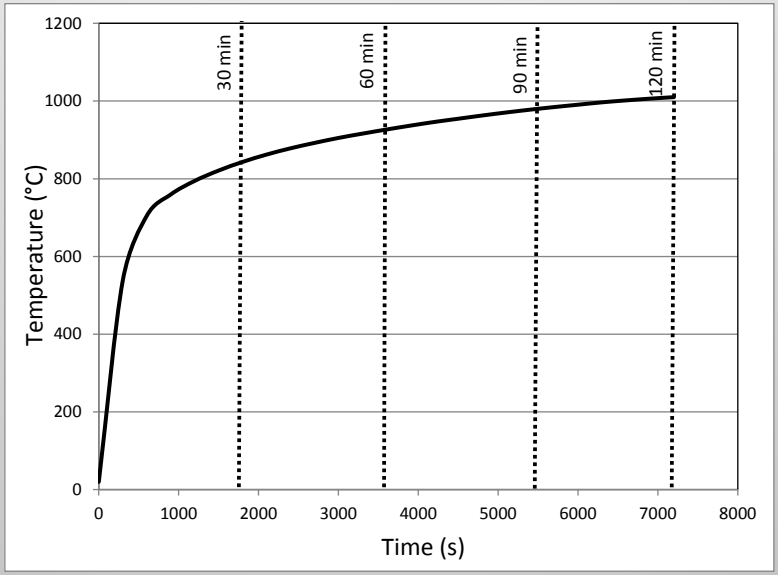

Figure 1 - ASTM E 119 Temperature-Time Curve

- ASTM E 119 method involves exposure of a portion of a full-scale fire barrier specimen to a severe furnace-fire environment that follows a monotonically-increasing temperature-time history

- ASTM E 119 specifies explicit acceptance criteria for rating of fire barriers, e.g.,
  - Barrier design has a 3-hour fire-resistance rating if the tested specimen meets specified acceptance criteria during at least 3 hours of a standard fire exposure

Background

- In 1953, fire duration based on the ASTM E 119 curve was correlated to fire load which included small quantities of flammable liquids, combustible furniture, and paper materials

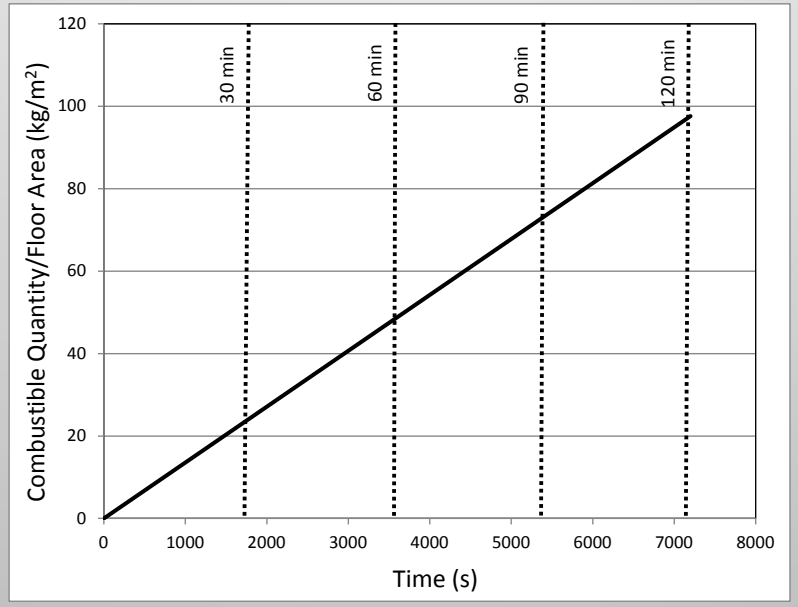

Figure 2 - ASTM E 119 Combustible Loading-Time Curve

- This correlation has been historically used in DSAs for establishing combustible loading limit SACs

Cases Evaluated for Comparison against ASTM E 119 Curve

Table 1 – Cases Considered

Case	Fire Growth Time (s)	$Q_{max,theoretical}$ (MW)	$\dot{V}$ (m^3/s)
Slow Growth Fire			
S1	600	20	0.1 (~212 cfm)
S2			1.0 (~2120 cfm)
S3			2.0 (~4240 cfm)
Medium Growth Fire			
M1	300	20	0.1 (~212 cfm)
M2			1.0 (~2120 cfm)
M3			2.0 (~4240 cfm)
Fast Growth Fire			
F1	150	20	0.1 (~212 cfm)
F2			1.0 (~2120 cfm)
F3			2.0 (~4240 cfm)
Ultra-Fast Growth Fire			
UF1	50	20	0.1 (~212 cfm)
UF2			1.0 (~2120 cfm)
UF3			2.0 (~4240 cfm)

Cases Evaluated for Comparison against ASTM E 119 Curve

- Used CFAST 6.2.0 to model all cases
- Compartment size of 12m (W) x 12m (L) x 9m (H) used for all cases (representative of a typical bay/laboratory)
- Compartment walls, floor, and ceiling assumed to be concrete with a thickness of 12” to minimize heat loss to outside
- Model includes a horizontal vent of 1 m^2 from the compartment to the outside to model leakages through cracks/openings
- Spectrum of ventilation flow rates considered envelopes a large number of typical bays/laboratories
- Maximum theoretical fire size of 20 MW was used in all cases to bound all potential fires that can occur in the compartment size considered (fire placed on the floor in the center of compartment)

Results for Cases Evaluated Compared to ASTM E 119 Curve

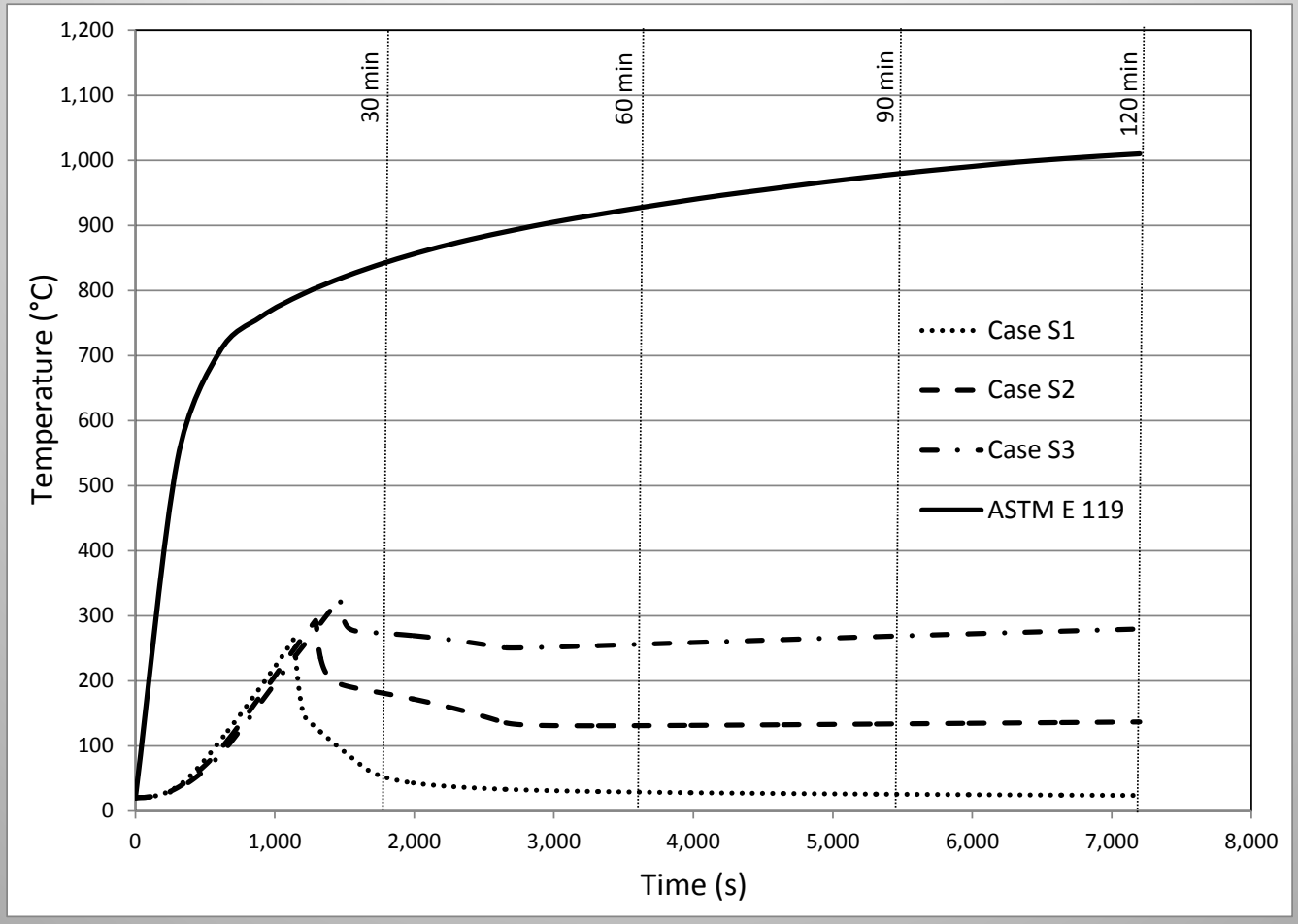

Figure 3 – ASTM E 119 Temperature-Time Curve vs. Temperature-Time Curves for Slow Fires

Results for Cases Evaluated Compared to ASTM E 119 Curve

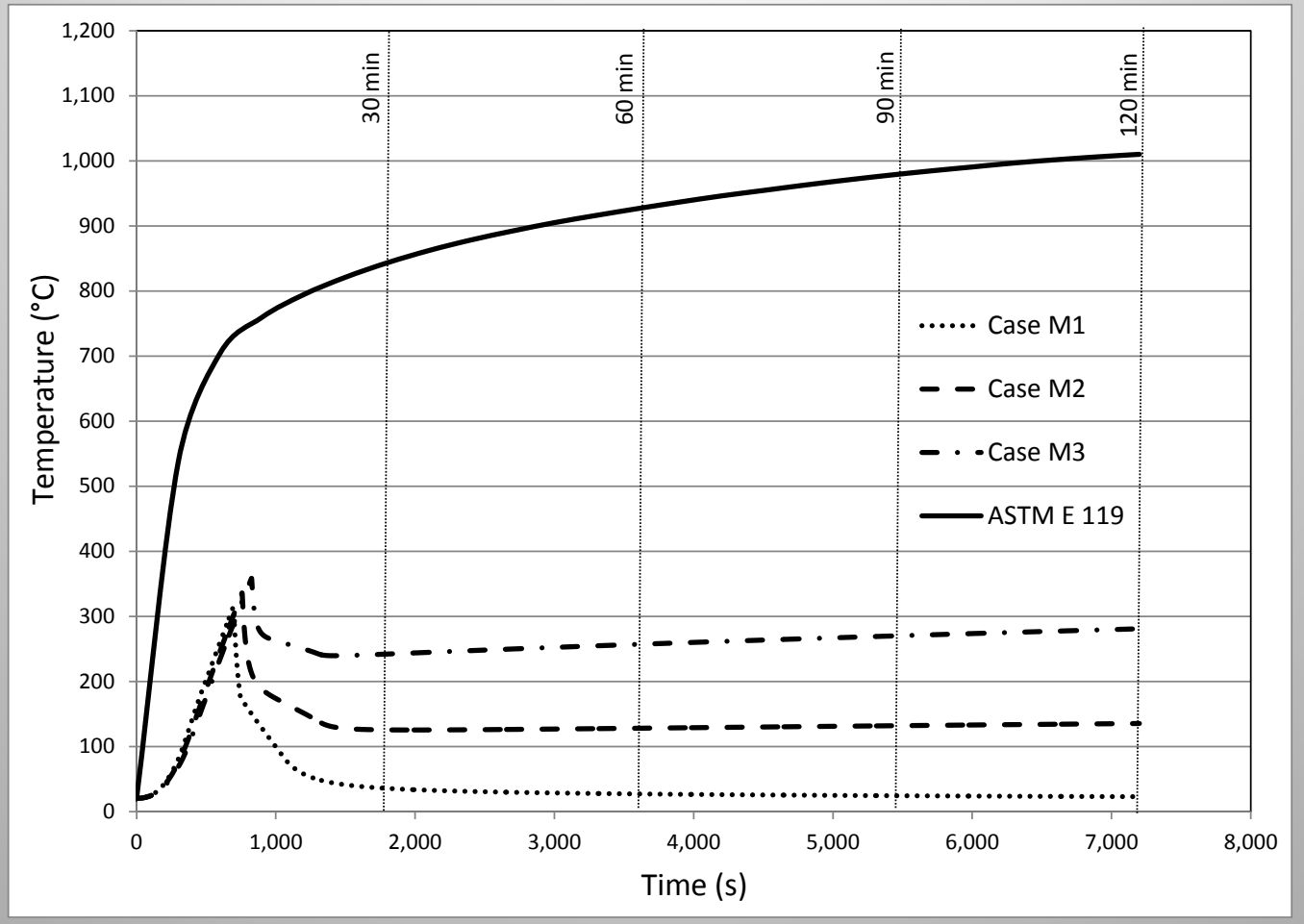

Figure 4 – ASTM E 119 Temperature-Time Curve vs. Temperature-Time Curves for Medium Fires

Results for Cases Evaluated Compared to ASTM E 119 Curve

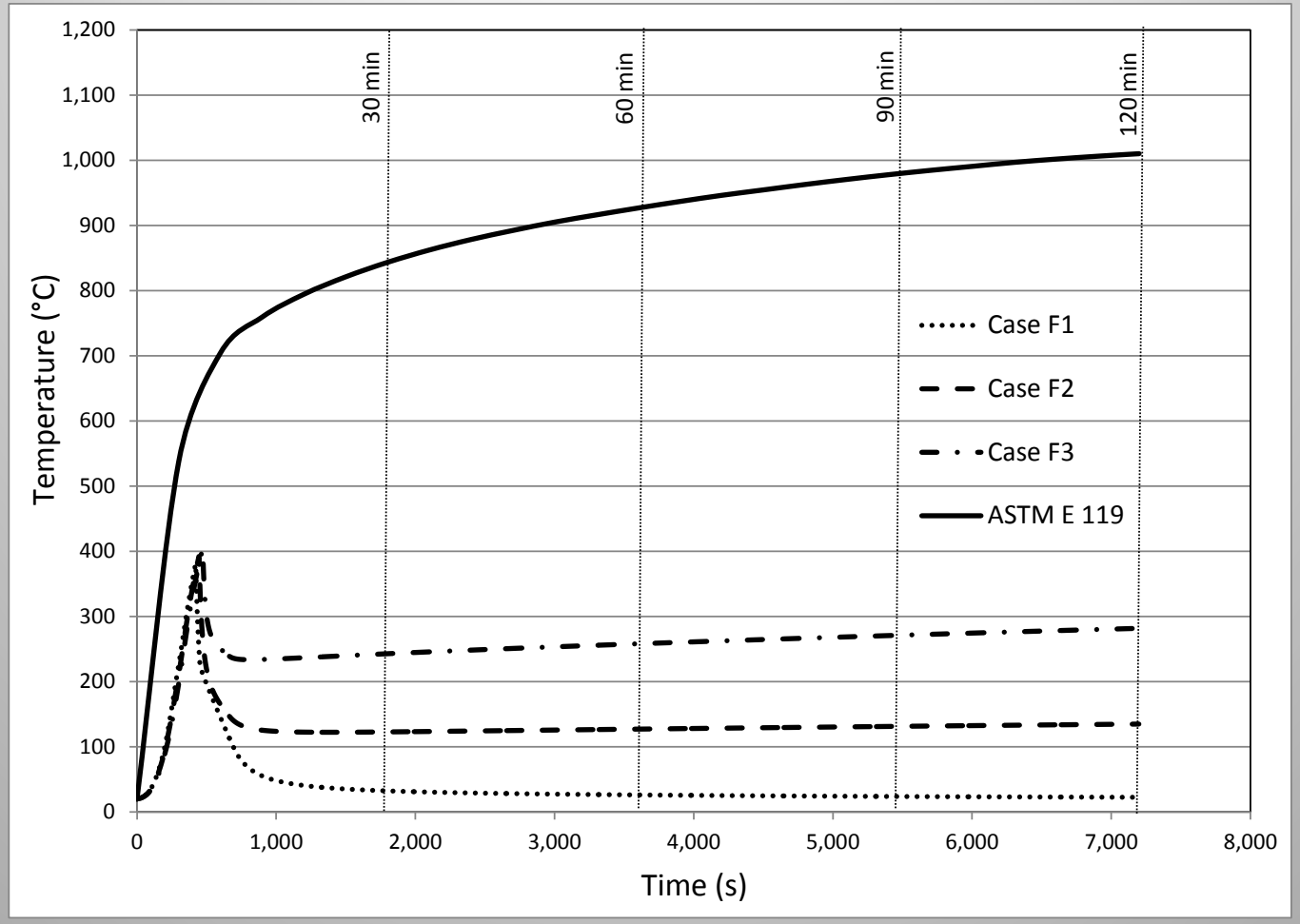

Figure 5 – ASTM E 119 Temperature-Time Curve vs. Temperature-Time Curves for Fast Fires

Results for Cases Evaluated Compared to ASTM E 119 Curve

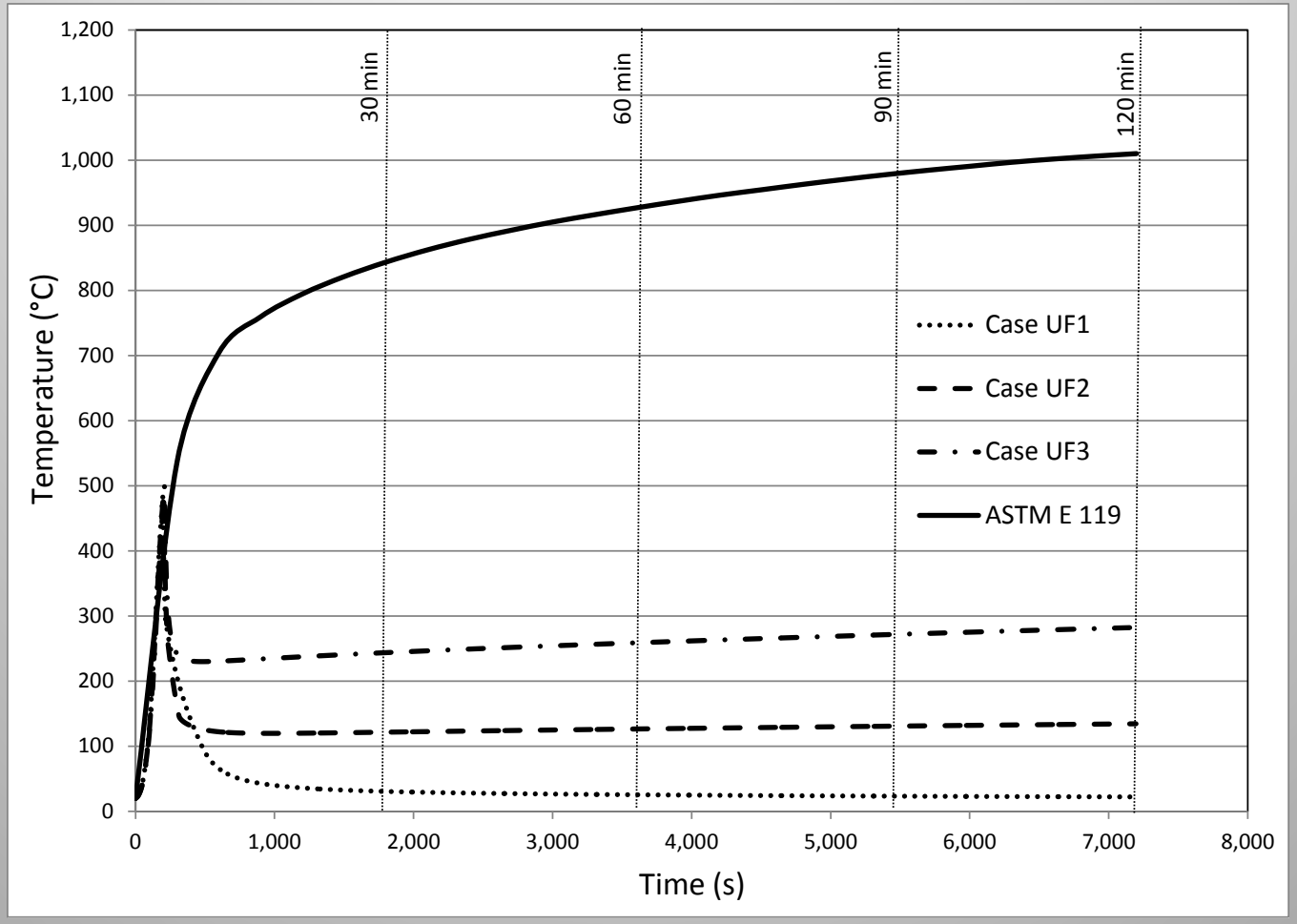

Figure 6 – ASTM E 119 Temperature-Time Curve vs. Temperature-Time Curves for Ultra-Fast Fires

Results for Cases Evaluated Compared to ASTM E 119 Curve

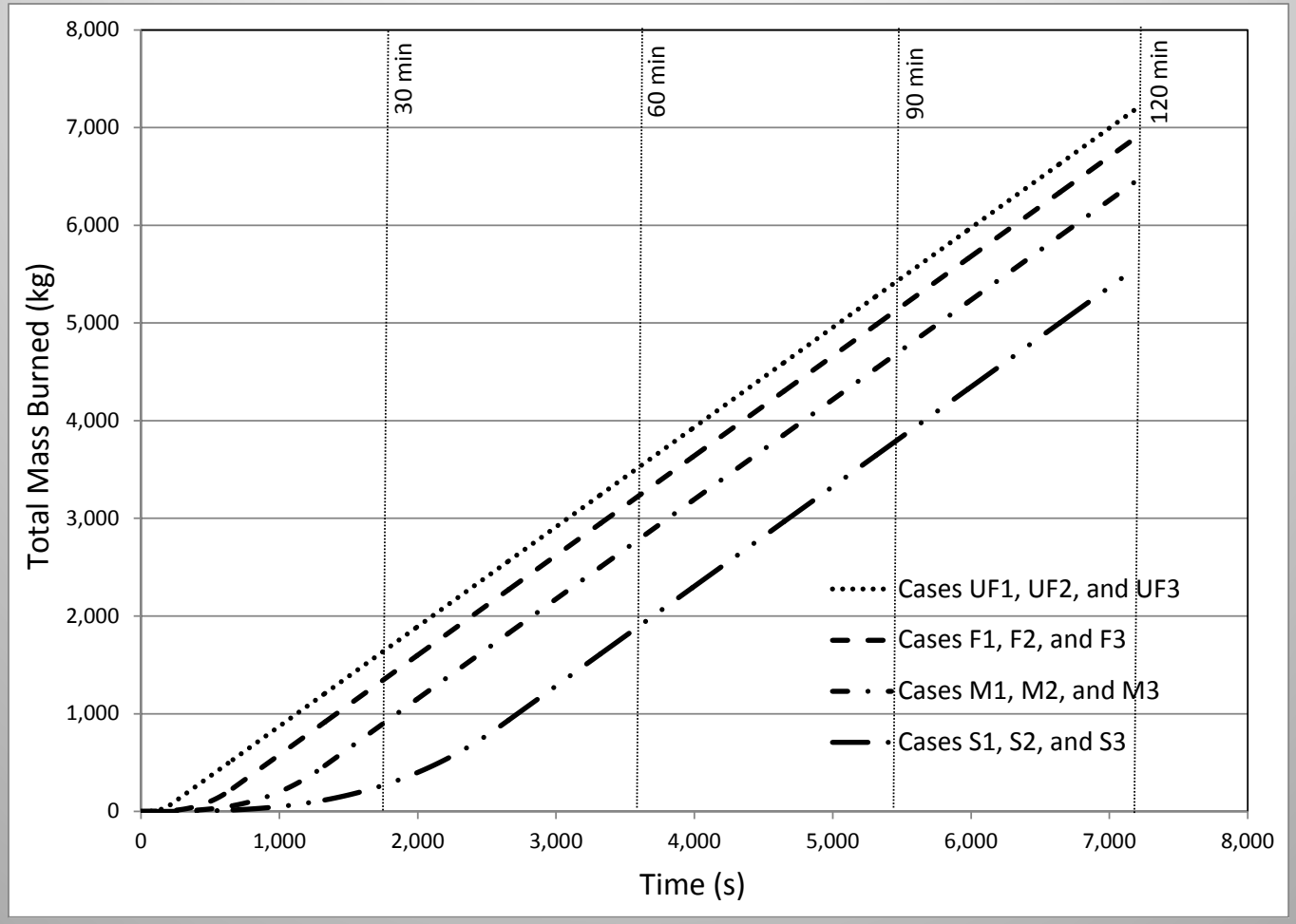

Figure 7 – Total Mass Burned vs. Time for All Cases

Results for Cases Evaluated Compared to ASTM E 119 Curve

Table 2
Calculated Combustible Loading Limits vs. ASTM E 119 Values[1]

Fire Duration	Fire Growth	Total Mass Burned (kg)	Combustible Loading Limit (Calculated)[2] (kg/m^2)	Combustible Loading Limit (ASTM E 119) (kg/m^2)
30 min (1800 s)	Slow	291	2.0	24.4
	Medium	950	6.6	
	Fast	1400	9.7	
	Ultra-Fast	1690	11.7	
60 min (3600 s)	Slow	1900	13.2	48.8
	Medium	2790	19.4	
	Fast	3230	22.4	
	Ultra-Fast	3530	24.5	
90 min (5400 s)	Slow	3730	25.9	73.2
	Medium	4620	32.1	
	Fast	5070	35.2	
	Ultra-Fast	5360	37.2	
120 min (7200 s)	Slow	5570	38.7	97.6
	Medium	6460	44.9	
	Fast	6910	48.0	
	Ultra-Fast	7200	50.0	

Notes:
- Values have been rounded off.
- Calculated combustible loading limits were obtained by dividing the total mass burned by the compartment floor area (144 m^2).

Results for Cases Evaluated Compared to ASTM E 119 Curve

Table 3
Combustible Loading for all Cases and Comparison to ASTM E 119

Time (min)	Combustible Loading (kg/m^2)				
	Slow Growth Fire	Medium Growth Fire	Fast Growth Fire	Ultra-Fast Growth Fire	ASTM E 119
30	2	6.6	9.7	11.7	24.4
60	13.2	19.4	22.4	24.5	48.8
90	25.9	32.1	35.2	37.2	73.2
120	38.7	44.9	48.0	50.0	97.6

Results for Cases Evaluated Compared to ASTM E 119 Curve

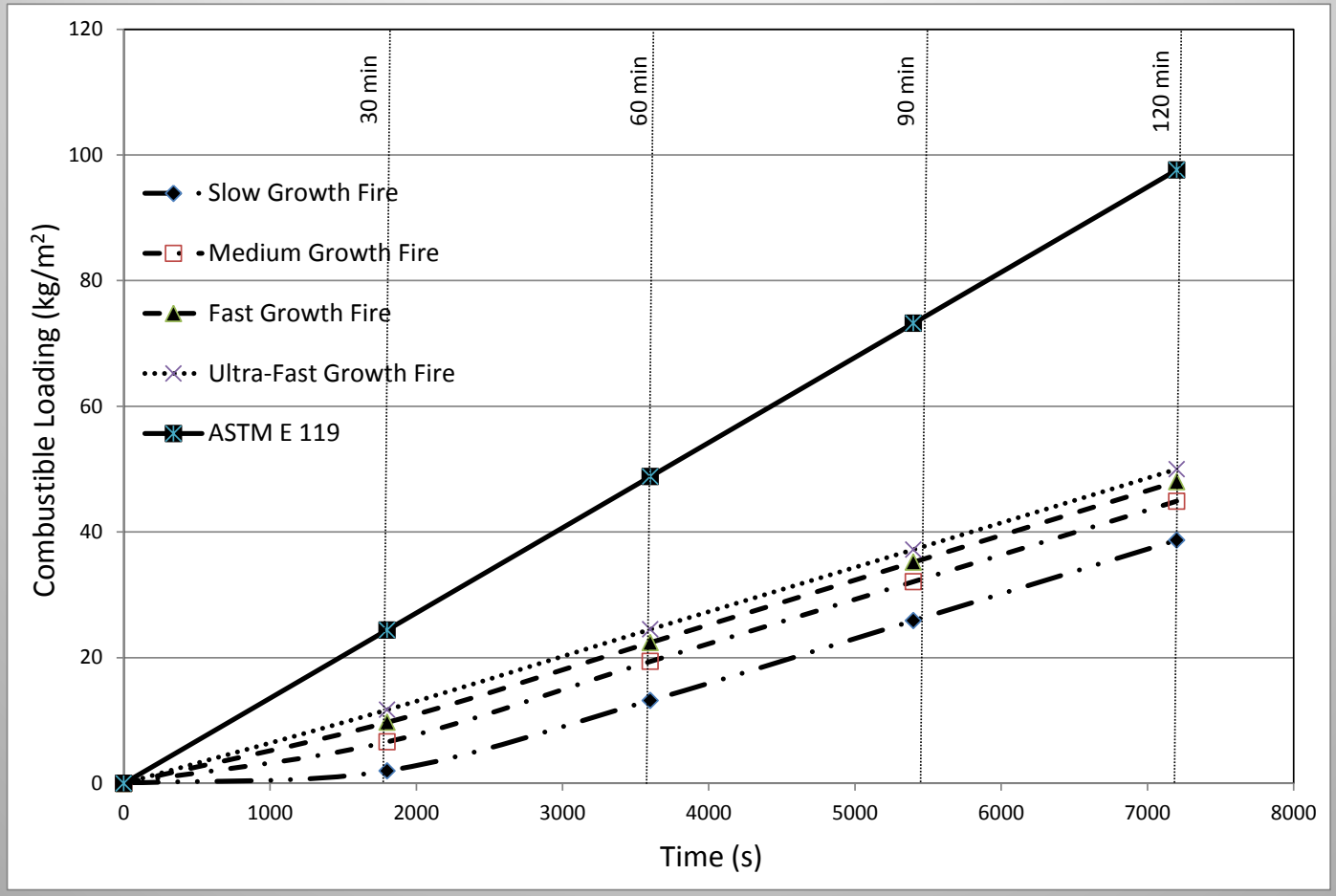

Figure 8 - Combustible Loading for all Cases and Comparison to ASTM E 119

Conclusions

- Compartment ventilation plays a big role on how large a fire can grow and the maximum temperature that can be attained in the compartment
- Combustible loading contributes to fire growth for as long as ventilation is available to support full combustion
- When compartment becomes ventilation limited, the combustible loading contributes only to duration of the fire
- Use of combustible loading based on ASTM E 119 curve for establishing SACs is overly conservative
- Compartment fire modeling should take into account type and configuration of material involved in the fire as well as effects of ventilation

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